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# BIOLOGICAL BULLETIN

## A WEEK WITH A MINING EUMENID: AN ECOLOGICO BEHAVIOR STUDY OF THE NESTING HABITS OF ODYNERUS DORSALIS FAB.

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### HABITAT.

At the edge of an extensive bottom-land farm near Lebanon, Ill., there is a large barren tract of land (Fig. 1, *B*). Its northern portion, which resembles roughly the continent of North America, is 80 feet long, 42 feet wide at its greatest breadth, and 9 feet at its narrowest. From the end that is 9 feet wide an arm 300 feet long tapers gradually until it is only 4 feet wide. In August, 1921, to the west and to the south of this desert there was a bottom-land cornfield covering several acres. The ascending slope and the upland on the east were covered with a dense growth of field sorrel, variegated with scattered iron weeds and mallow plants. On the western half of the northern boundary there was a cornfield, and on the eastern portion of that boundary there were plants similar to those on the east. Near the eastern edge of the barren tract the weeds were dwarfs, but they rapidly increased to normal size. From northeast to southwest and then south a small stream meanders through this land. The northern, especially the northeastern portion, is slightly higher and decidedly drier than the remainder. In meandering through the northeastern portion the streamlet maintains a uniform width of about six inches; in the remainder of the area it frequently widens into shallow lakelets. The flow of the water is continuous, but gentle. This apparently insignificant stream, which is the outlet of a spring with a decidedly salty taste, is the cause of all this barrenness. The minerals it conveys from that spring have destroyed the vegetation.

On the nearly level, but slightly higher, land about the headwaters of this brooklet, on the 26th of August, 1921, three colonies of *Odynerus dorsalis* were discovered (Fig. 1, *B, a, c, e*). One of these (Fig. 1, *A*) was on a spot that was absolutely barren; the other two were in spots the barrenness of which was partly interrupted by low-growing weeds (Fig. 1, *C*). At no other place in that desert strip, nor on any of the land for a half mile around, were there any colonies of this species. There, and at no other place in the neighborhood, were found the three essentials for the existence of this species: a patch of hard, dry, land, a near-by body of water, and a field infested with Hesperid caterpillars.

Evidently such a locality—a barren, or nearly barren, patch of dry, hard, ground, near-by water, accessible Hesperid larvæ—is the normal habitat of this species, for it is in just such situations that it has been found by Isely ('14, p. 282) and by the Raus ('18, p. 312). Hartman's statement ('05) that the species constructs mud nests on grass stems is the only discordant note in the literature, but his experience is radically so different from that of Isely, the Raus, and me that it is hard to believe that he is discussing the same species. Indeed, in a letter to Mr. Rau, Hartman states that it is probable that the species he discusses had been wrongly classified.

If one thinks in terms of social bees and hornets, the word populous could hardly be applied to these colonies; but they were slightly larger than those seen by Isely. Isely ('14, p. 293) writes: "*O. dorsalis* has a tendency to nest in colonies. I sometimes found an isolated nest, but usually the nests were in small groups, sometimes as many as eight. Usually only two or three wasps would share an open space in a pasture, each wasp digging one or two nests. I never found them in populous colonies like those of *O. papagorum.*" In speaking of *O. papagorum,* he says (*op. cit.,* p. 256): "Hundreds of them were at work there in the high banks of light earth." In the three colonies observed by me the number of wasps varied from twelve to sixteen. This estimate was made not by counting the wasps, but by noting the number of holes that were in process of construction or of being provisioned at the same time.

## Description of the Nests.

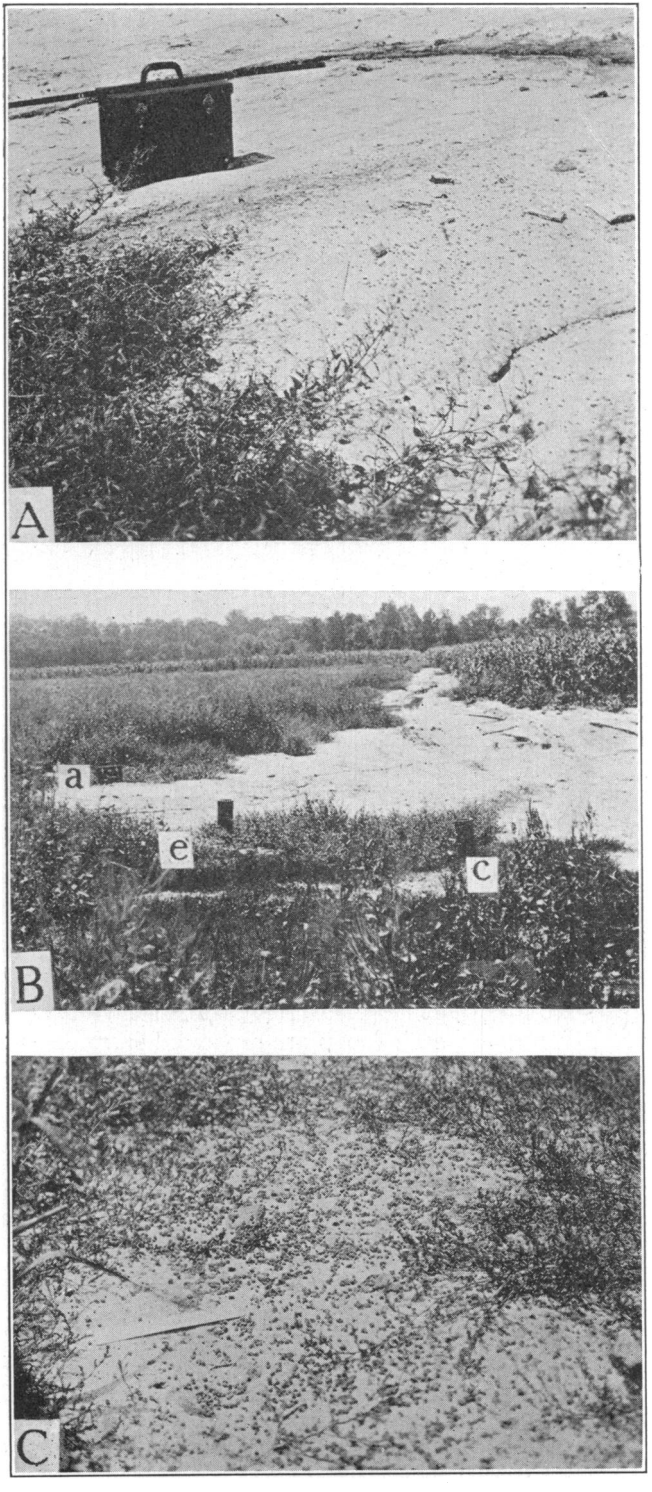
Each nest consists of one to three, usually two, barrel-shaped or sub-spherical cells for larvæ and a small air chamber, the latter being above the former. Thin partitions of clay separate the compartments from each other and a clay plug separates the whole from the outer world (Fig. 6, *B–D*). In the cases observed by me, when there were three cells, the upper was empty; when there were two cells, the upper was smaller than the lower. These nests vary in length from one and a half to two and three fourths inches. Each cell is about five eighths of an inch wide and the entrance to the nest is about three eighths of an inch. The transverse partitions are thin. Each wasp constructs a succession of nests which are arranged close together. These facts were ascertained by excavating twenty-five nests.

The above description harmonizes perfectly with Rau's observations and with the majority of Isely's; however, the latter author found some nests with as many as seven cells.

## Excavating the Nest.

The nest-building behavior of these wasps is fascinating. Preliminary to digging, the wasp makes sweeping movements over about forty square inches of surface. She moves about here and there as though testing the ground. The purpose of this survey I do not know; it may be that it enables her to detect the spots where other nests are located. This surmise is supported by the fact that excavations demonstrate that the nests occur in small groups. The nests of each group are separated from one another by walls that are not very thick; yet I have never discovered one burrow running into another.

The preliminary explorations over, the wasp makes a flight of orientation and then flies to the near-by streamlet and takes a deep drink of water. Returning to the spot selected, she moistens the ground and, with her mandibles, removes several pellets of dirt and conveys them, one by one, to a distance of from two inches to two feet. She then goes for some more water and then returns to the excavating (Fig. 3, *a*). This is repeated over and over again until the lower cell has been completed and the next one partly finished.


A
a
e
c
B
C

It usually takes a little over an hour to reach this point in the digging of the burrow. In removing the dirt she goes in head first and comes out backwards.

Isely thinks that this species carries the water in her jaws. He says ('14, p. 286): "Mrs. Wasp flew in the direction of the river and returned with her mouth parts glistening." Although I watched the wasps carefully, I failed to detect water glistening on their mouth parts. However, I know that they carry water to moisten the clay; because, immediately after a wasp that has returned from the streamlet applies her head to the ground, the clay glistens for a moment and then becomes dull. The water sparkles until it is absorbed by the clay. Hence I am inclined to believe, with the Raus ('18, p. 314), that the water is carried in some part of the digestive tract (probably the crop).

In a previous paragraph I have stated that each pellet, as it is removed, is carried to a distance of from two to twenty-four inches and deposited. How carried? According to Isely ('14, p. 285), she flies and drops them all, in about the same place, at approximately eighteen inches from the nest. The Raus ('18, p. 314) write: "She would then back out of her hole with a round, well-formed pellet of mud in her mandible, always fly from two to fifteen inches and drop it." They do not state whether the pellets are scattered around or deposited in one place, but the illustration furnished pictures them distributed, in a single layer, over the ground. Of the colonies I am describing, in one (Fig. 1, *B*, *a*) the pellets were scattered, in a single layer, over the plot; in the other two, in addition to the scattered pellets, there were piles of them near certain nests. Some wasps were flying and dropping the pellets, some were walking from the nest and depositing the pellets and then flying back to the nest, some were walking from the nest, depositing the pellets, and then walking back to it. It

FIG. 1. Views of the habitat of the colonies studied. *A*. Near view of the colony located at *a* in *B*. The specks on the ground are pellets dropped by the wasps. *B*. View of the environment of the three colonies: *a*, location of a colony situated where the ground is absolutely free from vegetation; *c*, location of a colony where a few low-growing weeds partly cover the ground; *e*, a colony similar to *c*. *C*. A near view of the colony located at *c* in *B*. The specks on the ground are pellets dropped by the wasps.

was readily seen that the piles of pellets were formed by the wasps that were walking and depositing pellets. Careful observation demonstrated that the piles of pellets were always associated with those nests that were partly covered by the low weeds growing on certain portions of plots *c* and *e*. What is the cause of this striking difference in the behavior of these wasps? Are some members of the species born with an instinct for flying and scattering pellets and other members of the same species born with an instinct for walking and depositing pellets, or is there some relation between the partial covering of nests by low-growing weeds and the change from flying to walking?

## Experimental Investigation of the Plasticity of the Carrying Behavior.

If some members of this species are born with an inflexible instinctive tendency to fly and scatter pellets and other members of the same species are born with a fixed instinct to walk and deposit them in piles, nothing in the way of an experiment can alter matters; but if, in response to a certain environment, the walking form of behavior has been derived from the flying, then it should be possible to experimentally demonstrate it. Since the low-growing weeds do not make flight impossible, if they are the cause of the change in behavior it must be because they render flying with a load so unpleasant that the insect takes to walking to avoid the unpleasantness. The problem that faced me was to devise some apparatus that would permit the insect to fly, but which, at the same time, would render flying with a burden so unpleasant as to cause the wasp to abandon the attempt.

In the experiments I used what might be called an interference maze, constructed out of stove wire. The maze was constructed in the field. A burrow was selected from which the wasp was flying and scattering pellets. Several pieces of wire were stuck, near together, in the ground near one of the nest openings. These wires were then so bent as to radiate over the burrow like the rays of a fan. Near the nest these wires were only an inch, or a little less, above the surface of the ground. As they extended outward they became gradually higher and higher until they

reached the point where they were bent abruptly to form a support. A series of sub-parallel, semi-elliptical wires were constructed across this fan-like expanse of wires (Fig. 2).

A number of these interference mazes were used. They were all similar, but no two were identical (Figs. 2 and 3 are from the same maze and Figs. 4 and 5 are from another). The only points invariably adhered to were two: first, in the immediate vicinity of the nest the wires were so arranged as to make it difficult for the wasp to get a flying start with her pellet of mud; second, the meshes were made sufficiently open for the wasp to fly through. Two mazes were used at a time. Each experiment extended over a period of from one to two hours. Three days were devoted to these experiments. The wasps, which invariably spent the night in the nests, became active between 7:30 and 8:00 A.M. and continued to work until about sundown. Each day the experiments were begun as soon as the wasps became active. On the first day they were continued until they became inactive; on the two other days I stopped work between four and five in the afternoon. Since two mazes were used at a time, this gave time enough for fifteen experiments.

The results of these experiments were conclusive and positive and sufficiently uniform to be epitomized in a single paragraph. In each case the wasp flew away with a few pellets (usually less than six) and then began to walk. In the midst of this uniformity there was individuality. The majority of the wasps walked from the nest, deposited the pellet (Fig. 2, *f*), and then walked back to the nest; some walked from the nest, deposited the pellet, then flew out of the maze and back to the nest. One walked to and from the pellet pile most of the time, but occasionally it would fly and scatter a pellet. Another would walk from nest to pellet pile and back until it came time to get some more water, then she would fly with the pellet out of the maze, drop it, and then go for water. Thus we have conclusive experimental proof that the walk-and-deposit-the-pellet behavior of these wasps has been derived from the fly-and-scatter-the-pellet behavior in response to an environment which made flying with a load unpleasant.

Occasionally, in arranging the maze over a certain nest, the

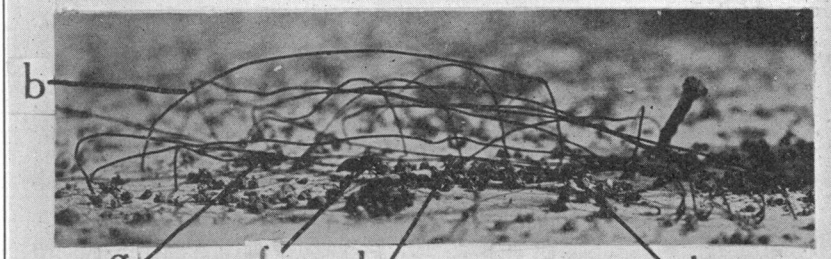



Fig. 2

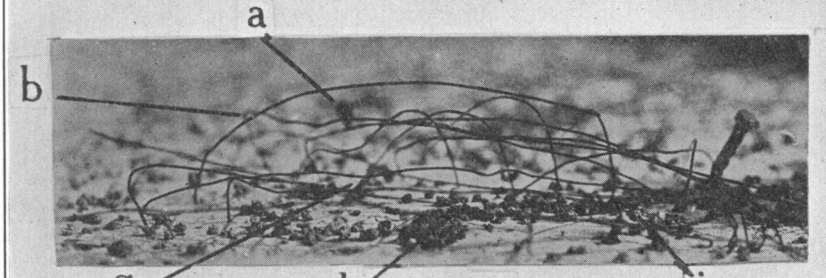



Fig. 3

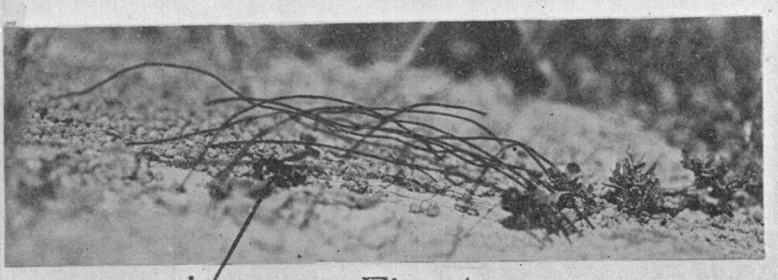



Fig. 4

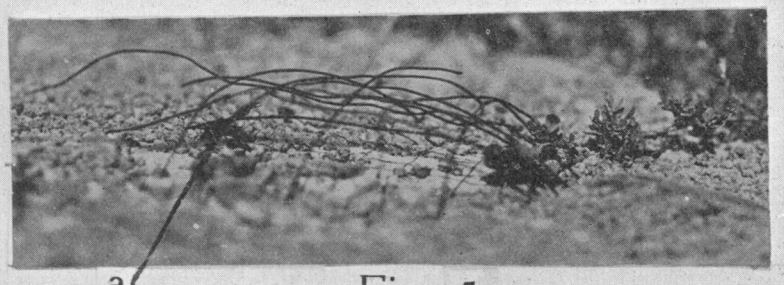



Fig. 5

higher portion of the maze would cover another nest in which the wasp was still digging. In such cases the second wasp would continue to fly and scatter pellets (Fig. 4, *j*; 5, *a*). Thus, in the same maze, I sometimes had one wasp walking and depositing pellets in a pile or piles and another flying and scattering them.

It is not claimed that these experiments predicate of wasps the power of logical thinking; on that topic experiments of this type are non-committal. However, they demonstrate conclusively that, in *Odynerus dorsalis* Fab., the walking-to-deposit-the-pellet behavior is derived from the flying-to-scatter-the-pellets activity, in response to a slight change in the environment.

## Experimental Interference with the Wasp When Excavating.

A series of experiments was conducted to test the reactions of excavating wasps to objects dropped into their burrows. Three kinds of objects were used in these experiments: pellets of dirt (mineral matter), short pieces of weed stems (plant matter), live caterpillars (animal matter).

Experiments with Pellets.—*Pellets of dirt that had been removed from nests by certain wasps were dropped into the partly excavated nests of other wasps.* In each case the wasp removed the pellet and disposed of it in the usual manner. In each case the return to the surface with the pellet was too quick to permit the formation of one.

Experiments with Bits of Weed Stems.—*Stems of the weed were cut into pieces about two inches long. These were placed in the partly completed burrows of the wasps. In some cases the*

Fig. 2. Showing a wasp that has been induced, by the maze, to walk and deposit her pellets: *b*, maze; *f*, wasp carrying the pellet; *g*, opening of the nest; *h*, piles of pellets deposited by the wasp; *i*, another wasp entering her nest to oviposit.

Fig. 3. Showing a wasp, that had been excavating inside the maze, flying for water: *a*, the wasp flying for water; *b*, the maze; *g*, entrance to the nest; *h*, piles of pellets deposited by the wasp; *i*, a wasp leaving her nest after depositing.

Fig. 4. Showing a wasp preparing to fly off with a pellet: *j*, getting ready for flight.

Fig. 5. Showing a wasp flying away with a pellet: *a*, a wasp flying.

*nest was so shallow that only half of a wasp could be hidden in it; in others the burrow was just deep enough to include the whole of the wasp.* Invariably the wasp removed the bits of weed and deposited them on the ground near by. Sometimes the wasp removed the weed stem or stems immediately; at others she continued excavating for a short time and then removed the foreign substance. It seems as though she removed the stems as soon as they greatly hampered her movements.

EXPERIMENTS WITH CATERPILLARS.—*Home-coming wasps were robbed of their prey until I had collected a dozen paralyzed caterpillars. Burrows in two stages of completion were selected: those that were just deep enough to half conceal the worker and those that were sufficiently deep to just hide the wasp. While the wasp was gone for water one of the caterpillars would be placed in the burrow and the nest watched until the wasp resumed her excavating. This was repeated over and over until the twelve caterpillars had been used.* With the exceptions of touches of individuality the behavior was invariably the same. The wasp always removed the caterpillar from the nest, flew with it to the weed-infested field, and returned empty-handed. In some cases the wasp flew away with the caterpillar as soon as arriving at the surface of the ground; more often she would climb some weed before flying away. Sometimes the journey was preceded by a longer or shorter flight of orientation, at others by none. The final flight was sometimes in one direction and sometimes in another, but always in the direction of the weed-infested field. Why did these wasps react so differently toward the several classes of objects? When pellets of earth were dropped into the nests, the wasps either flew and scattered them or walked and deposited them in piles; when short pieces of weed stems were placed in the burrows, the wasps deposited them on the ground adjacent to the nest; when paralyzed caterpillars were placed in the holes, the wasps flew with them to the insect-infested field, which was several yards away. I confess that every time a wasp flew away with a caterpillar it gave me an intellectual thrill; but, to me, the reason for the behavior remains a mystery.

## Homing Experiments.

While observing these wasps excavate their nests I was deeply impressed by two things: the facility with which the wasp, on returning with water, located her nest in the midst of surroundings which, to my senses, were almost uniform, and how easily she could be confused by slight changes in the environment. Almost any disfigurement of the surface of the ground would cause her to have trouble in locating her nest. Small pieces of tile and nails used to mark certain nests and radiating lines which I scratched about others caused confusion. In each case the reaction was the same. Arriving in the vicinity of the nest, the wasp would circle about in an irregular manner, sometimes afoot and sometimes awing, as though lost. After a certain length of time it would either find the nest or else abandon the attempt and start another. If the nest were found, before taking another trip afield, the wasp would always make a careful flight of orientation.

In the following words Isely ('14, p. 294) states how easily the wasps he studied were affected by changes in the surface of the ground: "Although not generally sensitive to observation, *O. dorsalis* was more responsive to changes in the surroundings of her burrows than was *O. papagorum*. A few marks with a knife, to assist in locating a nest at a later time, seemed to disturb one wasp considerably. On her return to the nest she made a prolonged flight of irregular circles above her nest, while she was in the habit of alighting without any hesitation. On another occasion I mutilated slightly the entrance to a burrow. Upon the wasp's return she circled around the burrow a few times and then alighted about two inches from the entrance. She flew away and returned in about a minute and repeated the observation performance. Again she flew away and returned without entering. This time she apparently deserted her nest."

Evidently, when in the neighborhood of the nest, *Odynerus dorsalis* finds her way by means of landmarks. How keen, then, must be her powers of observation since she sees landmarks in a situation where we see only uniformity!

## Provisioning the Nest.

The nests are stored with a black-headed, green, Hesperid larva, which the wasp obtains from the neighboring field. These are paralyzed and packed in the cell. The wasp carries the caterpillar dorsal side down and head to the front. When she reaches the burrow she pushes the caterpillar in ahead of her. Sometimes at one stage and sometimes at another in the provisioning of the nest the wasp folds her wings close to the body and backs into the nest (Fig. 2, *i*), attaches her egg to the roof of the cell by means of a cord about as long as the egg, and then comes out head first (Fig. 3, *i*) and resumes her work. This statement is an assumption based on the following facts: There is never found more than one egg suspended from the top of a cell; only once during the provisioning of the cell does the wasp back in; the attitude attained by backing into the cell is the most favorable one for attaching the egg to the roof. When this lower cell has been filled, the wasp fetches some water and then, out of the scrapings from the walls of what is to be the next cell, she covers the first with a clay wall. In most cases, after this partition has been formed, the second cell is the right size for receiving the provisions; occasionally the wasp must remove a few pellets before storing it with caterpillars. After it has been provisioned a mud cover is made for it out of scrapings from the wall of the upper portion of the burrow. The burrow is then closed with a plug of mud and dirt. The material to form this plug is scraped from the rim of the burrow; as a result the freshly formed burrow is topped with a saucer-like depression. After a few days, or even a few hours, the wind, the rain, and the pellet-dropping activities of other wasps obliterate the depression. To obtain sufficient water for the softening of the clay the wasp makes frequent trips to the near-by streamlet. During the whole time that the provisioning is progressing the burrow remains wide open. The above account tallies with those of Isely ('14, pp. 289–290) and the Raus ('18, p. 320).

## Experimental Interference with the Provisioning Activities of Wasps.

*While the wasp was in the nest arranging her provisions from one to four caterpillars were dropped into the burrow. Some of*

*these larvæ were obtained by robbing home-coming wasps; the majority were obtained by excavating nests that had been stored and sealed. Fifteen such experiments were performed.* On one occasion, when I had dropped two caterpillars into a nest, the wasp left the burrow and went hunting without removing them. Later in the day she took two caterpillars from her nest and carried them to the field; but there is no way of telling if these were the two added. On another occasion, when three caterpillars had been dropped into a nest and two deposited on the ground near the nest, the wasp, on emerging, captured one of the caterpillars that had been placed on the ground near the nest, flew with it to a near-by weed, stung it, malaxated it, and then carried it into the burrow. Immediately she emerged with a caterpillar and flew with it to the near-by field. She then continued to remove caterpillars from the nest until she had conveyed five to the field. In all other cases the wasp carried the caterpillars afield as soon as they had been dropped into the nest. It seems that the wasp is averse to using caterpillars that have been captured by some other wasp, and that she has some means of distinguishing them.

*To see if she could recognize her own captures, I frequently removed the prey from a home-coming wasp and dropped it on the ground among the nests.* Invariably she would search until she found the caterpillar and then would carry it to her nest.

*With a pair of forceps I occasionally attempted to remove the caterpillar from a wasp that was walking on the ground near her nest.* She would make strenuous efforts to retain her hold, occasionally stinging the larva. If I succeeded in removing the caterpillar, the wasp would search for it until found and then store it in her nest.

Isely ('14, p. 294) states: "*O. dorsalis* never seems to have any difficulty in finding her way to her burrow after a field trip. Usually she flies directly to it; I never saw her do otherwise when she was returning from the field with prey. At times, when she returned from the field unladen, I have seen her pause at another burrow in the colony. This action may have been prompted by curiosity instead of being a mistake in location." In that same connection the Raus write ('18, p. 320): "These wasps, when re-

turning from the field, seem to experience no difficulty whatever in locating their burrows. They carry their prey on the wing, usually with comparative ease, hugging it tightly all the while, alight at the brink of the hole and push it in ahead of them, holding it as they lower it; then they follow it into the hole, remain inside a few seconds—perhaps a half minute—and then come backing out. Sometimes the wasp soars away directly in quest of other game; at other times she sits down and washes her face for a moment, then rises and poises on vibrating wings an inch or two above the hole, turns around on the wing as if inspecting the site, then circles about and flies away. She is calm, gentle, and composed in all the maneuvers, betrays no nervousness, and wastes no time in blustering." Since I had read both of these accounts before making my observations on the same species, I was surprised to find that wasps coming from the field did sometimes have difficulty in finding their nests. My wasps, when arriving laden from the field, sometimes went direct to the nest and pushed the caterpillar in; but usually they did not. Frequently a wasp would examine the entrances to several nests before entering one. At other times a wasp afoot and awing would circle around and around for several minutes before entering the nest.

Movements as conspicuous as these, if performed by the wasps they studied, could not have been overlooked by such keen observers as Isely and the Raus. Why should my wasps behave so differently in this respect? I think I have the solution. In arranging mazes for experimental work, and in marking certain nests with bits of tile and with nails, I was continually disfiguring the ground. Since my wasps spent from ten minutes to more than half an hour on each hunting trip, it is quite likely that during the absence of a wasp the ground would be changed sufficiently to confuse her. A careful consideration of the records of my first afternoon's work confirms this opinion. Then the ground had not been disfigured with pieces of apparatus. To see if the colony was worth careful study, I made a few observations and marked a few nests. In most of the records of that afternoon the caterpillar-bearing wasps are described as going direct to their nests. Two records tell a different story and those two were connected with

nests that had been marked. I shall transcribe both of those records, because they have a direct bearing on this point. We shall call them records of wasp *A* and *B*.

*Record of wasp A:*

11:20 A.M. The wasp places a caterpillar in the nest and departs for the field. *I place a small piece of tile near the opening.*

11:30 A.M. The wasp returns with a caterpillar. She does not recognize the nest. She spends thirty minutes returning over and over to the same spot, but fails to recognize the nest.

12:12 P.M. *I remove the piece of tile.* Within two minutes the caterpillar is carried into the nest.

*Record of wasp B:*

11:34 A.M. The wasp carries the caterpillar into the nest, makes a flight of orientation, and then flies afield. *I place a small piece of coal to mark the nest.*

11:44. The wasp returns with another caterpillar, goes to the wrong hole, and, still bearing the caterpillar, flies about in irregular curves.

11:45. The wasp starts into the hole, leaves it and tries another. Still bearing the caterpillar, she flies about.

11:58. The wasp deposits the caterpillar in the nest and goes for water.

11:59. The wasp returns and begins to scrape the rim of the burrow and to add the material to the inside of the nest.

Evidently the wasp when returning with a caterpillar is just as sensitive to changes in her environment as she is when excavating.

I have a very strong suspicion, but not positive proof, that these wasps sometimes carry the caterpillar into the wrong nest. Occasionally I have seen a wasp, belonging to some nest upon which I had not experimented, remove a caterpillar and fly with it to the field. The Raus ('18, p. 324) have noticed the same thing. They write ('18, p. 324): "From one hole we saw an *O. dorsalis* emerging and watched her closely to ascertain her method of egress. Imagine our surprise when we saw her carry out a *P. catullus* caterpillar in her front and middle pair of legs, pause at the brink of the hole for several seconds to adjust the caterpillar properly between her forelegs and mandibles, and fly away with it." The

behavior of these wasps is identical with that of those into whose nests I had introduced caterpillars that had been captured by other wasps. It seems reasonable to assume that these caterpillars have been deposited in the nest by some other wasp.

## Time Required to Provision the Nest.

Isely found ('14) that many of the specimens examined by him excavated, provisioned, and sealed the burrows in less than two hours, although some of the individuals took a day for the work. In every case that I followed from beginning to the end the wasp always constructed the burrow one day and sealed it on the afternoon of the next day or the morning of the day after. Thus the time elapsing from the beginning of the excavation to the final sealing of the nest was twenty-four hours or more. Since the amount of time consumed in excavating the burrow was about the same in each case, the greater length of time required by my wasps to complete the work may have been due to lack of food. Isely's colonies were located where the mallow was abundant; my wasps were situated near a large field of field sorrel, scattered through which were a few mallow plants. On one occasion I followed a wasp, from plant to plant, for more than half an hour. She examined leaf after leaf, without finding any caterpillars. I uncoiled several leaves, but found them empty.

## Capturing the Prey.

Isely ('14, p. 289) writes as follows: "When *O. dorsalis* would come upon a crumpled leaf containing the larva of the spotted skipper, she would commence tearing energetically at the silken nest, first at one end and then at the other. Although the wasp worked furiously and without pausing, sometimes more than five minutes were required to dislodge the caterpillar. Usually, however, in less than a minute the caterpillar would be jerked violently from the cover, seized by the neck, and stung two or three times under the thorax. Once I saw a wasp seize a caterpillar by the tip of the abdomen, to jerk it out of the nest, and sting it under the last abdominal segments. Then she quickly seized the neck and gave it three thrusts under the thorax. A vigorous malaxation

invariably followed the stinging. The capture of a caterpillar usually caused considerable excitement on the part of the wasp. Sometimes she would lose her footing and both insects would roll from the leaf to the ground before the victim could be subdued."

Although I have watched this wasp searching the crumpled leaves for caterpillars, I have never been on hand at the moment she captured her prey. However, I have witnessed both the stinging and the malaxation of the victim. The first time I noticed the malaxation the wasp and the caterpillar were on the leaf of a weed and the wasp was vigorously crushing the neck of the larva with her jaws. Then the body of the caterpillar was moved forward until every portion of the body had been crushed by the rapidly moving mandibles. I witnessed the stinging on two occasions. Once a wasp captured a paralyzed caterpillar which I had placed on the ground near her nest. The larva was seized by the neck, the abdomen of the wasp curved beneath the caterpillar, and the sting of the wasp thrust into the thorax three times. On another occasion, by means of forceps, I was attempting to pull a larva away from a wasp. Suddenly she stung the caterpillar three or four times. These thrusts were in the front part of the abdomen. The stinging and the malaxation do not kill the caterpillars, but leave them in a semi-paralyzed condition. In all of the nests that I opened, if they contained eggs or young larvæ, the caterpillars squirmed when exposed to air.

## Visitors to the Colony.

During my week's sojourn with these wasps several species of insects visited the colony. A large species of assassin fly occasionally visited the scene. She would rest quietly on the ground in the midst of the colony and make her toilet. When a wasp approached she would become as rigid as a stone; but never did I see her make an attempt to capture one of the wasps.

Two species of dipterous parasites appeared. One fly (probably a species of *Hilarella*[1]) occasionally followed a laden wasp in

[1] The scientific names of all the visitors are not given; because, when they were common, the experiments required so much of my time that I could not capture them. On the afternoon that I set aside for capturing them no visitors appeared.

from her hunt. Just before the wasp entered the nest she made movements as though attempting to oviposit on the caterpillar. Another parasitic fly occasionally rested on the ground at the mouth of a nest from the time the wasp entered with a caterpillar until she emerged. She would then enter the nest, remain a short time, and then leave.

In excavating the nests of this species the burrows of two more mining Hymenoptera were found. One of the nests (Fig. 6, *A*)

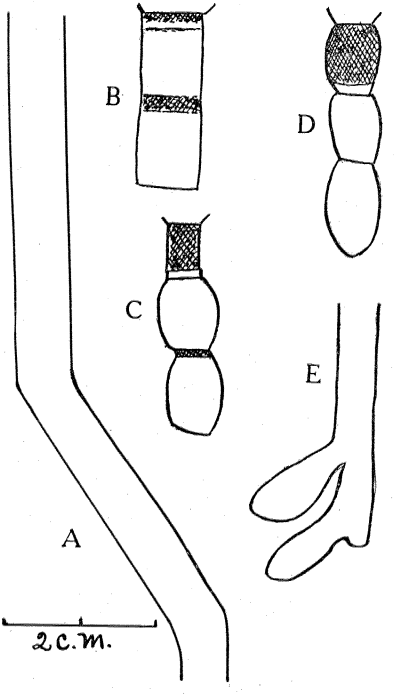



FIG. 6. Nests of certain wasps.
*A*, Burrow of *Cerceris* sp.? [Unfinished.]
*B–D*, nests of *Odynerus dorsalis* Fabr.
*E*, Burrow of an unknown visitor.

is an incompleted burrow of *Cerceris* sp.? I saw the wasp leave this nest. The other (Fig. 6, *E*) had a long vertical burrow; near the bottom of the shaft, on one side, were two cells. These cells made an angle of about forty-five degrees with the central shaft.

## CONCLUSIONS.

1. The habitat of *Odynerus dorsalis* is a level, or practically level, tract of barren or almost barren land situated conveniently to a supply of water and of Hesperid caterpillars.

2. The nests are constructed in the ground; they are vertical and consist of one to three, usually two, cells, which are separated from each other by clay partitions. In rare cases the number of cells may be larger than this.

3. They occur in colonies of moderate size.

4. In order to work the clay it is wet with water obtained by the wasp from some near-by stream, or pond, or puddle.

5. In excavating the nest the wasp works the soil into balls and carries it out of the nest. Normally she flies with the pellet to a distance of from two to twenty-four inches, but if overhanging vegetation or other impediment renders flying with a burden unpleasant, she walks and deposits the pellets in one or more piles.

6. During the periods of excavating and of storing the nest the wasp is guided by landmarks; this is evidenced by the fact that any changes in the surface of the ground always serve to make it difficult for her to locate the nest.

7. The eggs are attached to the roof of the cell by means of a short thread. There seems to be no definite stage in the provisioning of the nest for the oviposition. At that time the wasp backs into the cell to lay and then walks out head first.

8. The Hesperid caterpillars with which she stores her nest are packed in until the cell is full. Since the cells are not all of the same size, the number of caterpillars in the cells varies. In all of the nests examined by me the lower cell is the larger.

9. In all of the cells examined by me the caterpillars were active enough to squirm when exposed to the light and the air.

10. If, during her absence to get water, pellets of mud or bits of weed stems are dropped into her nest, the wasp, on returning, removes them and deposits them on the ground near the nest. If paralyzed caterpillars are dropped into such a nest, under the same conditions, the wasp will fly with them to a distance of several yards.

11. If caterpillars captured by another wasp of the same species

are deposited in nests of wasps that are provisioning their nests, they will be removed and carried to a distance of several yards.

12. When slight changes are made in the surface of the ground near the nest, wasps returning home laden with caterpillars have difficulty in finding their homes, and sometimes enter the nests of other wasps.

13. In the midst of a colony of these wasps other mining Hymenoptera sometimes establish burrows.

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